

June 28 2007

**IEEE POWER ENGINEERING SOCIETY  
ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE**

**PANEL SESSION: AFRICAN AND MIDDLE EAST ENERGY DEVELOPMENT AND  
POWER GENERATION ---STATUS OF RENEWABLE ENERGY PROJECTS,  
SUSTAINABILITY OF INFRASTRUCTURE, LARGE AND SMALL-SCALE  
DEVELOPMENTS, AND JOINT VENTURE AND CROSS-BORDER PROJECTS#  
Room Technical CC #12**

Wednesday June 27, 8:00 a.m.~1:00 p.m.

Tom Hammons, Pat Naidoo and Bai Blyden

**IEEE 2007 General Meeting, 24-28 June 2007, Tampa, FL, USA.**

**Sponsored by: International Practices for Energy Development and Power Generation  
Subcommittee**

Chairs: Tom Hammons, University of Glasgow, Scotland, UK.

Pat Naidoo, ESKOM, South Africa

Bai Blyden, The BBRM Group, LLC, USA

## **INTRODUCTION**

On behalf of the Energy Development and Power Generation Committee, welcome to this Panel Session on African and Middle East Energy Development and Power Generation---Electricity Infrastructure: Status of Renewable Energy Projects, Sustainability of Infrastructure, Large and Small-scale Developments, and Joint Venture and Cross-Border Projects

The Panel will focus on the present status and future prospect of electricity infrastructure in Africa from the viewpoint of generation and transmission development, global deregulation trends and policies, advances in global research and development and strategies to influence integration into the global transition to knowledge based economies in Africa. The panel will evaluate and update models and policies that are near-term, mid term and long term.

Presentations will be by eminent specialists on African electricity infrastructure and will be focused on projected development of regional power pools as a development strategy while taking into account the importance of distributed generation in this strategy. The panel seeks to follow the paradigm that contemplates challenges of the 21<sup>st</sup> century.

The Session presents some results of studies in this area at this time.

Panelists and Titles of their presentations are:

1. Pathmanathan Naidoo, Eskom, South Africa and Lawrence Musaba, Manager, Southern African Power Pool, Harare, Zimbabwe; Fundamental Elements for the Forward Planning of the “*Cape to Cairo*” Interconnected Power System (Paper 07GM 0636).

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# Document prepared and edited by T J Hammons

2. Pathmanathan Naidoo, Eskom, South Africa, BPC; and J.T.Lokala, Westcor, Gaborone, Botswana. Defining the Terms of Reference for Feasibility Studies for the Western Power Corridor Project in Southern Africa. (Invited Discussion).
3. Pathmanathan Naidoo, Eskom South Africa; and Nelson M. Ijumba, HVDC Center, University of KwaZulu, Natal, Durban, South Africa. A Novel Approach to Providing On-Route Power Supplies to Rural and Urban Communities in Close Proximity to Extra High Voltage DC Transmission Lines. (Invited Discussion).
4. Adnan Al-Mohaisen, General Manager, GCC Interconnection Authority, Saudi Arabia; Luc Chaussé, Project Director, Transmission & Distribution Division, SNC-Lavalin Inc. and Satish Sud, Vice President, Power Systems Energy Division, SNC-Lavalin Inc., Montreal, Quebec, Canada. Progress Report on the Gulf Cooperation Council (GCC) Electricity Grid System Interconnection in the Middle East (Paper 07GM0456).
5. Pathmanathan Naidoo, Eskom, South Africa; Lawrence Musaba, Southern African Power Pool, Harare, Zimbabwe; Fernando Sousa, Electricidade de Mocambique, Mozambique; and Mark Dingle, Eskom South Africa. Planning the Eastern Power Corridor of Southern Africa (Paper 07GM0743).
6. F. Masawi, Motraco, Mozambique; Pathmanathan Naidoo and W. Majola, Eskom South Africa; and T. J. Hammons, Glasgow University, UK. Analysis of Performance of an African Joint Venture Company Established for the Transport of Bulk Power from Eskom, South Africa to Swaziland, Mozambique and the Mozal Aluminum Smelter in Maputo (Paper 07GM1285).
7. Katherine Steel, MIT, USA. A System Dynamics Approach to Understanding the Development of the Kenyan Electric Power Sector (Paper 07GM0967).
8. Stephen R. Connors, Director, MIT Laboratory for Energy and the Environment, MIT, Cambridge, MA, USA. Providing Electricity Services to Rural Africa (Paper 07GM1035).
9. Bai Blyden, Engineering Consultant, BBRM Group, Elk Grove, CA, USA. Exploring a Systems Dynamics Approach to Institutional Development and Integration in the African Power Development Sector (Paper 07GM0915).
10. Pathmanathan Naidoo, D. Muftic and A.C. Britten, Eskom, South Africa; N. M. Ijumba, University of KwaZulu, Natal, South Africa, C. T. Gaunt, University of Cape Town, South Africa; and T. J. Hammons, Glasgow University, UK. Considerations for the Planning of UHVDC Schemes in Southern Africa (Paper 07GM1309).
11. Wei-Jen Lee, Energy Systems Research Center, University of Texas at Arlington, TX, USA; Bai Blyden, BBRM Group, Elk Grove CA, USA; and Alusine Jalloh, Evaluating Autonomous Systems with Hybrid Generation Facilities in support of Fishing Villages (Paper 07GM1327).

Each Panelist will speak for approximately 20 minutes. Each presentation will be discussed immediately following the respective presentation. There will be a further opportunity for discussion of the presentations following the final presentation.

Tom Hammons (Chair of International Practices for Energy Development and Power Generation, University of Glasgow, UK), Pat Naidoo (Senior General Manager [Special Projects], Office of the Chief Executive, Eskom, South Africa), and Bai Blyden (Engineering Consultant, BBRM Group, LLC, USA) have organized it.

Tom Hammons, Pat Naidoo and Bai Blyden will moderate the Panel Session.

The first presentation is by Pathmanathan Naidoo, Eskom and Lawrence Musaba, Manager, Southern African Power Pool, Harare, Zimbabwe and discusses the Fundamental Elements for the Forward Planning of the “Cape to Cairo” Interconnected Power System. Pat Naidoo will present it.

South Africa continues to set the international benchmark for electricity prices. South Africa also provides the largest percentage of the electricity used on continental Africa. Based on this historical

strength of favorable electricity prices, the plans are to even lower the prevailing electricity prices by adding more hydro-based renewable energy with mid merit and peaking support from environmentally friendly gas based generation. There exists a sufficient quantity of both gas and hydro at acceptable and affordable rates. The first building block of the continental grid would be the regional interconnected power system of the regional power pools. This is discussed. The next building phase will involve the use of extra high voltage DC for bulk power transfer between the participating regional power systems. The expected result is sharing in the diversity in primary energy sources; all contributing to a lower end user cost of electrical energy. The continent has the capability to become the energy intensive valley of the world; supporting the developed world in the ongoing battle with global warming.

**Pat Naidoo** is Senior General Manager in the Office of the Chief Executive of Eskom South Africa. He has completed over two decades of engineering service to Eskom and now focuses on sourcing, lower cost, renewable, bulk electrical energy for continental consumption. Currently he is working on the power generation and power transmission technologies in association with environmental and financial requirements so as to yield longer-term sustainable business solutions.

The second presentation is an invited discussion on defining the Terms of Reference for Feasibility Studies for the Western Power Corridor Project in Southern Africa. Pat Naidoo, Eskom South Africa and J.T.Lokala, Westcor, Gaborone, Botswana has prepared it. Pat Naidoo will present it.

The return of peace and stability to Southern Africa has promoted a surge in growth of customer demand for electrical energy. The region boasts some of the best renewable hydro energy sources coupled with the environment teeming with wild life, game, fauna and flora. Balancing growth requirements with environmental impact concerns have promoted a two-part feasibility assessment of the proposed Western Power Corridor project in Southern Africa. Supported by the regularity of water flows, a run of river power station is proposed at the Inga 3 site on the Congo River. For large-scale bulk power evacuation, extra high voltage direct current transmission will be a requirement. This presentation introduces the large-scale project and defines terms of reference for the feasibility studies.

The third presentation is another invited discussion. It is entitled A Novel Approach to Providing On-Route Power Supplies to Rural and Urban Communities in Close Proximity to Extra High Voltage DC Transmission Lines. Pat Naidoo, Eskom South Africa; and Nelson M. Ijumba, HVDC Center, University of KwaZulu, Natal, Durban, South Africa have prepared it. Pat Naidoo will present it.

Extra high voltage DC transmission is planned for the many power corridors of the Continental African Grid. These lines will traverse the countryside and will pass over many rural and urban communities. These communities will in general have no formal access to grid electrical energy. Access to electrical energy for the basics of light and heat will provide a better quality of life for all. It is an expectation of the engineering design that such access is provided affordably. Laboratory based studies of HVDC sources have shown that conventional corona cages can capture corona energy and make available a continuous energy source. This will be evaluated. The low levels of the energy source may require that the energy be employed in association with a conventional battery or solar energy source. The corona energy is always available and will serve as a continuous recharge for the batteries employed. This arrangement provides a unique and novel approach for the use of the corona energy, which would otherwise be lost to atmosphere radiation. There is no charge for the otherwise lost energy and every tower of the DC circuit could have the corona cages installed and built at time of line construction. The dimensions of the cage can be optimized to serve other DC line requirements.

The fourth presentation summarizes a progress report on the Gulf Cooperation Council Electricity Grid System Interconnection in the Middle East. Adnan Al-Mohaisen, General Manager, GCC Interconnection Authority, Saudi Arabia; Luc Chaussé, Project Director, Transmission & Distribution Division, SNC-Lavalin Inc. and Satish Sud, Vice President, Power Systems Energy Division, SNC-Lavalin Inc., Montreal, Quebec, Canada have prepared it. Satish Sud will summarize it.

The presentation describes the strategy adopted for implementation of the interconnection between the Gulf States (Kuwait, Saudi Arabia, Bahrain, Qatar, UAE and Oman) to ensure a competitive price for the project. The presentation also describes progress in the implementation and the issues that have had to be faced to date. Activities are being carried out to define the organizational structure of the Gulf Cooperation Council Interconnection Authority and the interconnection agreements that will provide the framework for the operations.

**Satish Sud** graduated with a B.Tech. (Honors) in Electrical Engineering from the Indian Institute of Technology, Kharagpur, India and obtained his M.Sc.degree in Engineering from the University of Manitoba, Winnipeg, Canada. He is Vice President in the Transmission and Distribution Division of SNC-Lavalin. He is an electrical engineer with over 36 years of experience and is responsible for the development and management of the Power Systems Group that undertakes electrical transmission and distribution projects, electrical system and energy studies, master plans, power sector reform and restructuring studies, and economic and financial studies.

The next presentation is on Planning the Eastern Power Corridor of Southern Africa and has been prepared by Pat Naidoo, Eskom, South Africa; Lawrence Musaba, Southern African Power Pool, Harare, Zimbabwe; Fernando Sousa, Electricidade de Mocambique, Mozambique; and Mark Dingle, Eskom South Africa. Lawrence Musaba will present it.

The eastern corridor of Southern Africa has hydro, gas and thermal energy sources. Emanating from the South African National Grid thermal power stations, two 400kV transmission lines connect the port City of Maputo and the Swaziland Edwaleni substation to form the first part of the proposed Eastern Corridor. This is with the joint venture company, Motraco. From Maputo, the lines can run northwards to the port city of Beira and then onto Cahorra Bassa hydroelectric power station. Cahorra Bassa supplies Zimbabwe, Mozambique and South Africa and planned Malawi. This power station has the potential for expansion at the North Bank. Lower downstream, another power station, Mpanda Unuca is proposed. Interconnecting these power stations will provide a very strong base for further extensions northwards to Dar-es-Salaam and with a DC tee –off to Madagascar. Madagascar is an island load off continental Africa. In addition to the thermal and hydro energy sources, gas could also enter the power generation sector. At present, gas is imported by the Sasol Plant, in South Africa, as primary feedstock into the coal to gas to liquid petroleum conversion process.

**Lawrence Musaba** graduated with a BEng degree with Distinction from the University of Zambia in 1989, an MSc degree in 1991 and a PhD in 1996, both from the University of Manchester Institute of Science and Technology (UMIST) in the UK. Dr. Musaba worked for Midlands Power International in Birmingham, UK, as Assistant Project Development Manager until September of 1998, when he was appointed Head of the Department of Electrical and Electronic Engineering at the University of Zambia. He was appointed the Southern African Power Pool Co-ordination Center Manager in February 2002.

The sixth presentation discusses an Analysis of Performance of an African Joint Venture Company Established for the Transport of Bulk Power from Eskom, South Africa to Swaziland, Mozambique and the Mozal Aluminum Smelter in Maputo. F. Masawi, Motraco, Maputo, Mozambique; P. Naidoo and W. Majola, Eskom South Africa, and T. J. Hammons, Glasgow University, UK, have prepared it. F. Masawi from Mozambique will present it.

The quality of electricity supply delivered to the national utilities in Mozambique and Swaziland and the energy intensive customer, BHP Billiton–Mozal aluminum smelter is defined as world class. Two series compensated 400 kV transmission lines provide the 1200 MW of electrical energy to the participating customers. The joint venture company collated the skills and experiences of the shareholders and directed the focused effort to achieve the sterling business results. Customer satisfaction has contributed to application for more power. The presentation will highlight the achievements that were accomplished in the development.

**F. Masawi** is with Motraco, Maputo, Mozambique;

The seventh presentation discusses a System Dynamics Approach to Understanding Development of the Kenyan Electric Power Sector. It has been prepared and will be presented by Katherine Steel, MIT, USA

In many African countries there is tension between grid and off-grid electric service provision and it is unclear whether centralized or decentralized power system architecture will emerge. This presentation explores some of the dynamics of system development in Kenya, where poor grid infrastructure has resulted in a thriving private market for photovoltaic panels and a growing number of industries are investigating shifting to on-site generation. The presentation is based on ethnographic interviews and observations in Kenya and makes use of System Dynamics modeling tools to analyze qualitative and quantitative feedback in the system.

**Katherine Steel** is with the Laboratory for Energy and the Environment & Program on Emerging Technologies, Engineering Systems Division, Massachusetts Institute of Technology, Cambridge, USA. MIT, USA

The eighth presentation discusses the provision of electricity services to Rural Africa and has been prepared and will be presented by Stephen R. Connors, MIT, Cambridge, MA, USA

The international community has set ambitious goals aimed at improving the quality of life in Africa. Initial delivery of electric service to rural Africa is far from a "one size fits all" technical solution, especially given the seasonal diversity of energy needs, as well as the availability and quality of candidate renewable energy resources. Nor will be the expansion, and potential integration, of those systems over time be a simple task.

To design, implement and operate cost-effective and reliable rural electricity systems many factors must be taken into account. The technical and economic feasibility of different systems is highly dependent on a diverse set of design criteria: local energy demands (daily, seasonal); available renewable resources (quantity and quality); location relative to conventional fuel supplies and/or grid power; plus how these factors may vary over time. Dynamics among technical and institutional aspects are key, as are understanding the relative economic value of staged electric service introductions. Key design factors towards the deployment of electricity services will be identified and assessed in the presentation.

**Stephen R. Connors** is Director, Analysis Group for Regional Energy Alternatives, Regional Electricity Alternatives Laboratory for Energy and the Environment, Massachusetts Institute of Technology, Cambridge, MA, USA

The ninth presentation reviews exploring a systems dynamics approach to institutional development and integration in the African power development sector. Bai Blyden, Engineering Consultant, BBRM Group, Elk Grove, CA, USA has prepared and will present it.

This presentation furthers the development of previous recommendations made for institutional and manpower development efficiency to support the growing African Energy Sector. Developing and standardizing a curriculum at strategically selected technical centers and universities throughout the countries of the various regional power pools are the strategic recommendation of this study.

**Bai K Blyden** is Engineering Consultant, BBRM Group, USA. He received the degree of MS.EE from the Moscow Energetics Institute in 1979, specializing in Power Systems, Generation and Industrial Distribution Systems with a minor in Computers. He is currently a Project Manager with the Cummins Power Generation Group responsible for Distributed Generation CoGen projects in California where he resides. Mr Blyden has worked on over thirty power plants and their associated interconnections throughout his career in various capacities of Electrical Systems design, operations planning, management and construction. He has lectured extensively on African Energy Development issues to Institutions and more recently to Investment groups. Mr. Blyden is an early advocate of an Integrated African Grid and presented a conceptual framework and technical analysis for a centralized African Power pool with links to North Africa at the first IEEE Region 8 conference held in Nairobi, Kenya, December 1983

The penultimate presentation is on Considerations for the Planning of UHVDC Schemes in Southern Africa. It as been prepared by Pat Naidoo, D. Muftic and A.C. Britten, Eskom, South Africa; N. M. Ijumba, University of KwaZulu, Natal, South Africa; C. T. Gaunt, University of Cape Town, South Africa; and T. J. Hammons, Glasgow University, UK. D Muftic will present it.

This presentation describes a simple approach to the planning of long distance electric power transmission systems for Southern African conditions. In common with China and India, significant sources of hydroelectric generation in Southern Africa are situated far from the main load centers. This applies particularly to the single site large hydroelectric resource of 44GW at Inga on the Congo River in the Democratic Republic of Congo and to the more than 100GW distributed sources across Central, West and East Africa. In all cases, the nearest major load centers are about 3000 to 6000 km away. The salient question is how to reliably and securely transport high power levels of up to 6 GW over this distance. This presentation describes the results of the preliminary investigations into developing the transmission master plan for the Western Power Corridor project in Southern Africa.

Pat Naidoo, D. Muftic and A.C. Britten are with Eskom, South Africa.

The final presentation concerns Evaluating Autonomous Systems with Hybrid Generation Facilities in support of Fishing Villages. It has been prepared by Wei-Jen Lee, Energy Systems Research Center, University of Texas at Arlington, TX, USA; Bai Blyden, BBRM Group, Elk Grove CA, USA; and Alusine Jalloh, The African Program, University of Texas at Arlington, TX, USA

The availability of affordable and reliable energy is one of the most crucial requirements for economic development and modernization of developing countries. This is particularly important in Africa. With a population of 13.4% of the world and a land area of 15%, Africa has only 2% of the world's industrial capacity. Its per capita income is only 15% of the world average and only consumes 3% of world energy. Today, less than 15% of Africa's population has access to electricity where much of the available supply is unreliable. In addition to regional cooperation and integration through energy pooling and cross-border energy trading, a balanced Distributed Generation strategy through modified micro grids has been proposed in the previous discussions. This presentation serves as continuation of a distributed micro grid application specific to small towns and villages fishing processing potential. This development will serve as primary building blocks for future system expansion. Issues regarding the potential resources for hybrid distributed generation and reliability of power supply will be addressed.

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